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CARWASH WASTEWATERS: CHARACTERISTICS, VOLUMES, AND TREATABILITY BY GRAVITY OIL SEPARATION**AGUAS RESIDUALES DE LAVADO-ENGRASADO AUTOMOTRIZ: CARACTERÍSTICAS, VOLÚMENES Y TRATABILIDAD**

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Abstract

The aim of this research was to determine the characteristics, volumes and treatability of Full-service carwash wastewaters in Toluca (Mexico State). The average water use for Exterior-only wash was 50 L per small-size car and 170 L per medium-size vehicle (pick up, van or light truck). The Full-service wash (exterior, engine and chassis) required 170 L per small-size car and 300 L per light truck. Wastewaters were generally emulsified and contained high contaminant loads (in average, 1100 mg/L oil and grease, 4500 mg/L COD and 3500 mg/L Total Suspended Solids). Gravity oil separators used in the car washing facilities were able to reduce the pollutant loads (showing a 80 % efficiency) but usually not enough to meet the sewer discharge standards or reuse requirements. The data provided by the study are useful for screening the applicable technologies and setting the design capacity of the reclaim systems that are needed in the Mexican car washing sector.

Keywords: vehicle; wastewaters; washing; water use; oil-water separator.

Resumen

El objetivo de esta investigación fue evaluar las características, volúmenes y tratabilidad de las aguas residuales procedentes de talleres de lavado-engrasado en Toluca (Estado de México). Los resultados mostraron que se gastan en promedio, 50 L de agua en el lavado de carrocerías de vehículos compactos y subcompactos, frente a 170 L, para camionetas y vans. En el servicio completo de lavado-engrasado (carrocería, motor y chasis), los volúmenes de agua requeridos fueron en promedio de 170 L para autos chicos y 300 L para camionetas. Las aguas residuales son generalmente emulsionadas y contienen altas cargas contaminantes (en promedio, 1100 mg/L de aceites y grasas, 4500 mg/L DQO y 3500 mg/L de sólidos suspendidos totales). Los separadores convencionales de aceite y grasas que se utilizan en los talleres de lavado son capaces de reducir las cargas contaminantes (eficiencia de 80 %), pero no siempre esta disminución fue suficiente para llegar a producir un efluente conforme a los límites de descarga en el alcantarillado o satisfacer un objetivo de calidad para el re-uso del agua. Los datos que provea el estudio son útiles para ayudar a seleccionar las tecnologías aplicables y tamaño de procesos de tratamiento que se requieren en el sector de lavado-engrasado en México.

Palabras clave: vehículos; aguas residuales; lavado-engrasado; tasa de uso de agua; separador de aceites.

1. Introduction

Studies carried out in different parts of the world have shown that the car service and maintenance sector constitutes a potential source of soil, water and air pollution (US-EPA 1991; Duke and Chung 1995; WEF 1995; Paxéus 1996). Based on the experience gathered from reported cases in the U.S.A, a survey of car wash facilities was initiated in Toluca (Mexico State) to evaluate the environmental conditions of these small businesses, more specially with respect to the wastewaters. As far as we know, there is not any published paper in the currently and

reasonably accessible literature that focused on studying the characteristics of the carwash wastewaters in Mexico.

According to reports from the National Institute of Statistics, Geography and Informatics of Mexico (INEGI 1999) there were 148682 centers for repair and maintenance of automobiles and trucks in Mexico in 1999, among those, 1506 centers were located in the municipality of Toluca (capital of the State of Mexico, with 670000 inhabitants). In the same year, there were 8595 Full-service car wash facilities in the country and 97 in Toluca.

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Within the car service sector, carwash shops are growing environmental concerns according to the public perception. Because of water use, car washing constitutes a highly visible activity which is scrutinized by public and policy makers, especially during periods of droughts or water shortages (Brown 2002a). Since 1999, the International Carwash Association (ICA, Chicago, IL.) has undertaken several studies to determine the average water consumption per vehicle washed (Brown 2002b), characteristics of the discharges (Brown 2002a) and water conservation and reclaim techniques (Brown 1999) in the US professional carwash industry. The average water consumption per vehicle washed reported by Brown (2002b) is 57 L, 129 L, and 163 L for self-services, conveyor and in-bay wash categories, respectively. In contrast, Rosenblum (2001) reported a general mean value of 177 L per car. Another report of the ICA (Brown 2002a) claimed that oil/water separator tanks, in professional carwashes, are able to meet standard requirements of the pretreated effluent. Samples of the effluents, collected at the discharge points of different facilities, contained around or less than 100 mg/L of oil and grease (O&G), between 150 to 890 mg/L COD (Chemical Oxygen Demand) and 6 to 117 mg/L TSS (Total Suspended Solids). Similar studies and data were also reported by the Westminster City Water resources (AWWA 2002) and the Australian Water Corporation (AWC 2003). Although the automatic car washing, as practiced in US industry (conveyor, in-bay and self-service), is scarce in Mexico, the data from the ICA, AWC and Westminster City may be a baseline for comparisons.

Best management practices in the automotive repair and maintenance sector recommend the use of oil-water separators for spill control, for leaks containment and for wastewater pretreatment (WEF, 1995; US-EPA, 1991). Compared to coalescers, the conventional oil-water separator is seen as a more accessible technology (simplicity of construction, lower maintenance requirements and cost) where limited financial resources and lack of skills play a pivotal role. The best-known criteria for the design of gravity oil separators are those presented by the API (American Petroleum Institute), but they are only strictly applicable to effluents from refineries. These standards include various requirements, for example, a minimum depth of three feet (API, 1990), which cannot be applied in the case of smaller flows. In addition, in washing effluents, the presence of soaps and degreasers may produce emulsions and prevent the adequate performance of any gravity separator. Then, since gravity separators are frequently encountered in the carwash sector in Mexico, it is pertinent to evaluate the limits of this technology with respect to the sewer discharge standard (NOM 02: DOF 1998) and for reuse scenarios.

The results reported in the present study are part of a larger research whose objective was to carry out an environmental evaluation of car repair and maintenance services in Mexico. In that broad research, more than 150 visits to car shops were made in Toluca. A sample of 60 facilities of all types (general mechanics, transmission, car wash, tire repair, change of oil, batteries, dismantling and resale of used parts, etc.) was submitted to a detailed environmental evaluation based on a questionnaire (US-EPA 2003) and a software program (EcoTaller) developed for this purpose (Garduño and Morales 2003).

The results presented in this paper focus on the car washing sector. The specific objective was to determine the characteristics, volumes, and treatability of carwash wastewaters. The aim was to highlight the environmental problematic and provide basic data required for the development of pollution control technologies needed in the sector.

2. Methodology.

2.1 Defining the sample of facilities evaluated

Due to the great similarity in the *modus operandi* of each type of facility, it was decided to select a non random sample of 13 representative carwash shops, based on the most common practices, geographical location, willingness of owners and managers to cooperate and budget limits.

For the car cleaning sector (Table 1), the sample was composed by Exterior-only wash shops and Full-service wash facilities (engine, chassis and exterior, locally known as wash-lubricating services). The interest to study these sites was to quantify the flow rate of the washing systems (hoses and high pressure trigger guns) that are used, estimate the length and average water consumption per vehicle, characterize the discharges and evaluate the efficiency of the pretreatment systems (oil-water separators). Not all the previous mentioned activities were done in each facility, but at least, three samples from three different shops were collected and analyzed to determine the average reported values. The individual reported measurement from each shop (e.g. water use per vehicle) was obtained by calculating the arithmetic mean of different replicates (3 to 4) while the physico-chemical characteristics were obtained based on a composite sample collected when a car was being washed (1 L per 2 min).

2.2 Measurement of the average water use per vehicle

The operation modes followed in these facilities may be grouped in two main categories, according to the way how water is provided: 1) use of buckets to throw water to the cars ("bucket-fulls"),

Table 1: Conformation of the carwash' sample

Identification of the shop			Type of information obtained in each shop				
#	Code	Type of service	Hose flow rates and/or bucket volumes	Average water use per vehicle		Characterization	
				Body washing	Body, motor and chassis Washing	Influent	Separator effluent
1	T009-Gon	Full-Service Wash	X	X	X	X	X
2	T028-Sup	Full-Service Wash	X	X	X	X	X
3	T029-Xin	Full-Service Wash	X		X	X	X
4	T030-Laz	Full-Service Wash	X	X	X	X	X
5	T032-Tol	Full-Service Wash				X	X
6	T016-Ang	Full-Service Wash	X	X	X	X	X
7	T106-Som	Full-Service Wash	X	X	X	X	X
8	T006-Acu	Express Exterior-only wash (small cars)	X	X			
9	T014-Che	Express Exterior-only wash (small cars)	X	X			
10	T0349-Ofe	Express Exterior-only wash (small cars)	X	X			
11	T350-Bro	Express Exterior-only wash (small cars)	X	X			
12	T042-Rof	Full-Service Wash (new car dealer)					X
13	T063-Yve	Full-Service Wash (new car dealer)					X

2) use of hose or pressure gun connected to the municipal water supply system or to a water pump.

The water use per vehicle washed was estimated by means of measuring the flow rate supplied by the washing system (hoses and/or pressure guns) and recording the time of operation. In the case of "buckets" washing, the number of containers used during the process was counted and multiplied by the average volume of a bucket. The measurements for each of the two groups of vehicles (compact vs vans & light trucks) and two levels of service (Exterior-only vs Full-service wash) were obtained from a sample of 3 to 4 shops.

2.3 Characterization of wash wastewaters

In order to determine the characteristics of raw effluents (before pre-treatment), composite samples were taken at the outflow streams during the total wash time of a vehicle. The composite samples

(1 to 2 per facility) were collected in 6 different Full-service shops. In one of the facilities (Shop # 3), a more extensive sampling was undertaken (4 composite samples were collected every hour for 4 hours). This shop was selected to evaluate an oil/water separator prototype, as described latter.

The parameters analyzed were: pH; conductivity (Cond); solids as total suspended solids (TSS), total dissolved solids (TDS) and their volatile fraction; chemical oxygen demand (COD); oil and grease (O&G) and Methylene Blue Active Substances (MBAS). All parameters were measured in accordance with standard methods (APHA 1989).

The oil emulsion level was determined by collecting an aliquot of 4 L from the composite samples to submit it to a susceptibility test by gravity separation. This treatability assay allows estimating the concentration of emulsified oil fraction that cannot be eliminated by free flotation, according to a procedure developed by the *American Petroleum*

Institute (API 1990). The procedure consists in decanting the collected sample for 30 minutes inside a separation funnel and then to pick up, through suction, an aliquot of 1 L from the clarified water phase located in the lower part of the funnel. The residual O&G concentration in the clarified water sample represents the amount of oil in emulsion.

2.4 Evaluation of the performance of existing oil separators in car wash facilities

As shown in Table 1, nine Full-service carwash shops were included in this part of the study. The data from the separator of Shop #3 will be presented separately in later sections, as it was a prototype designed and built *in situ* during this study in order to evaluate its performance under controlled conditions. In 6 of the 8 remaining shops, both the inflow and outflow were analyzed to be able to evaluate the separator performance either in absolute (residual concentration of oil) or relative (efficiency of separation) terms. At the other two carwash shops, the samples were only taken from the outflow of the processes to evaluate the residual oil concentration with respect to the applicable sewer discharge standard (NOM 02: DOF 1998).

2.5 Design, construction and evaluation of a prototype oil-separator

The performance of existing conventional separators in shops does not allow drawing a final conclusion regarding the limits of this type of technology (small API oil/water separators) to treat the effluents of carwash services. One reason might be that these pre-treatment systems are not always strictly designed according to established standards. To address this gap, an oil/water separator prototype was designed and built based on some of the API (1990) criteria which were applicable (oil drop cut > 150 μm), and on optimization essays carried out at lab-scale in a previous research (López-Vázquez and Fall 2004).

The prototype was built in Shop #3 (see Table 1), a typical Full-service carwash facility, taking into account a design flow rate of 38 L/min as calculated during the sampling campaign. Before starting its evaluation, the separator was in service for 45 days. Hourly grab samples were taken at the inflow and outflow of the separator. They were analyzed to determine the O&G, TSS and COD concentrations, according to standard methods (APHA 1989).

The impact of the use of detergents and soaps on the efficiency of the separator was evaluated by performing oil separation susceptibility tests for each inflow sample, as previously described. The samples collected were analyzed to determine the content of O&G and MBAS (5540C method: APHA, 1989).

3. Results and discussion

3.1 Environmental profile of Exterior-only and Full-service carwash shops in Mexico

It is important to note the difference between the Full-service and Exterior-only wash in U.S.A and Mexico. In the U.S. automatic carwash sector, the Full-service refers to cleaning the interior (vacuuming and wiping) and exterior, while the Exterior-only service means that interior cleaning is not included. In common carwash practices in Mexico (hand-held wash), the interior vacuuming and wiping is always part of any type of service, so that the Full-service implies washing the exterior (body, motor and chassis) and interior vacuuming, while the Exterior-only includes washing the body and vacuuming.

In Mexican cities, such as Toluca, carwash shops are primarily of two types: the first one is composed by express services devoted to Exterior-only washing for small cars (compact and subcompact), light trucks and vans. While the second type comprises businesses, locally known as wash-lubricating facilities, that not only clean exteriors, motors and chassis (Full-service) but also perform lubricating and oil change activities.

Express carwash shops normally have between 3 and 6 work stations with floors of concrete. Wastewaters are discharged into the sewer through the drainage system of the shop (without any oil separator) and manholes are used as traps for solids catchment. They perform Exterior-only wash with hoses or buckets (wetting, rubbing with detergents or shampoos, rinsing and finally hand drying with towels).

On the other hand, carwash-lubricating shops in Mexico (with 2 to 3 work stations equipped with hydraulic lifts) are very similar to truck washing practices in U.S. High pressure guns, tap water, hand-held brushes, detergents and degreasers are used for grit and oil removal from the motor, chassis and body of cars and trucks. After drying the motor and chassis, oil or diesel is sprayed as a protective treatment. These pollutants are washed off during the next car wash. A large variety of aqueous commercial degreasers are used. In many cases, these products are bought in bulk and without labels to let the user know their exact composition. Some facilities use a mixture of water, diesel and detergent as degreasing agent. The change of oil, usually done in the same area as the washing, is prone to cause leaks that finally end in the wastewater. In addition, it was noticed that the majority of carwash-lubricating facilities has oil/water separators.

3.2 Water use in carwash servicing

Table 2 shows the volume of water that is used for Exterior-only wash according to the size of

vehicles (small cars *versus* vans and light trucks). The average water use is determined primarily by the size of the vehicle, but the wash procedure (pressure hoses and guns, or buckets), the experience of the operator and how dirty the vehicle is may influence. While a compact car requires an average of almost 50 L during approximately 25 minutes of wash time, a van or light truck needs approximately 170 L and 30 minutes.

During the visits to several carwash shops, it was observed that the clients are mainly owners of small cars, vans and light trucks. Heavy vehicles are not often serviced in this type of public businesses (only 1 to 2 trucks or bus per day) because most of truck and bus companies have their own wash stations. Future research will focus on this segment of the market.

Nevertheless, there are some specialized businesses exclusively dedicated to Express Exterior-only wash of buses. Based on a limited number of visits (to only two shops) to this type of business, it seems that the "Express exterior-only wash" of buses use less water (93 L and 33 min wash time per bus) than the Exterior-only wash of vans and light trucks (170 L, 30 minutes) performed in Full-service shops, even though buses are larger vehicles and they are washed with buckets. This issue was primarily attributed to the fact that shops specialized in bus express-washing, a common activity around terrestrial transport stations, are very eager to save water, as their supply, in the case of Toluca, is done by truck tanks at a relatively high cost.

The average water use per vehicle in the US automatic carwash industry (57 L, 129 L and 163 L, for self-services, conveyor and in-bay wash categories, respectively - Brown 2002b) is similar to the range of mean values (50 to 170 L per vehicle, Table 2) observed on the Mexican hand held, Exterior-only wash sector. However, the time of the service is longer in the last case.

Table 3 presents the volume of water used and the time required for a Full-service wash (exterior, motor and chassis) of vehicles of different sizes. It shows that almost 170 L of water and nearly an hour were needed for small cars compared to approximately 300 L and 80 minutes for vans and light trucks.

The Full-service of heavy trucks was not thoroughly studied, but a brief sampling campaign undertaken in only one shop yielded a volume of 600 L during 1.5 hours for a 10-ton truck and 1100 L and 3.5 hours for a trailer. For comparison purposes, in an evaluation of 10 heavy vehicles carwash facilities in the United States, Fink (1996) reported an average of 880 L water consumption per truck, while Paxéus (1996) found a mean of 1200 L per truck in a study done in Switzerland. The values observed in this study (for trucks) are within the range of the reported values.

The flow rates of the hoses and high pressure guns used in the shops were very different (between 5 and 36 L/min, with an average of 15 L/min). Most of the shops have between 2 and 4 hoses or guns. The average flow rate that would be reached after applying wastewater equalization principles (column V/t, on Table 2 and 3) oscillates between 1.4 and 7.2 L/min per work station pad, depending on the type of service and vehicle size. This data is useful for setting the range of capacity for the reclaim systems that are needed in the Mexican carwash sector.

Table 2. Water use and service duration per vehicle for Exterior-only wash

Type of vehicle	Type of service	Volume used V (L/vehicle)	Duration of service, t (min)	V/t (L/min)
Small cars (compact and subcompact)	Mean	48	23	1.9
	CV(%)	33%	13%	22%
	Min-Max	34-69	20-25	1.4-2.4
	N	5	5	5
Vans and light trucks	Mean	169	30	5.6
	CV(%)	39%	7%	36%
	Min-Max	100-230	28-32	3.3-7.2
	N	3	3	3

Min - Max: minimum y maximum; CV (%): Coefficient of variation ($100 * StdD/Mean$); StdD: Standard deviation; N: Total number of samples.

*: Two shops more that are listed in Table 1 (#10 and 11) are excluded from the statistics in Table 2 because they represent a different size of vehicle (bus), separately commented in the text.

Table 3. Water use and service duration per vehicle for Full-service wash

Type of vehicle	Type of service	Volume used V (L/vehicle)	Duration of service, t (min)	V/t (L/min)
Small cars (compact and subcompact)	Mean	173	55	3.3
	CV(%)	22%	38%	22%
	Min-Max	114-217	37-95	2.2-4.4
	N	7	6	6
Vans and light trucks	Mean	306	80	4.2
	CV(%)	16%	31%	37%
	Min-Max	269-388	55-113	2.5-5.5
	N	5	5	5

3.3 Wastewater characteristics from the Full-service carwash sector

Table 4 shows the results of the characterization. Based on these data, wastewaters from the Full-service carwash sector (wash lubricating shops, as practiced in Mexico) contain high concentrations of O&G, COD and TSS (on average, 1100 mg/L O&G, 4520 mg/L COD and 3561 mg/L TSS). Solids are predominantly inorganic matter (approximately 70 % of the suspended and dissolved solids), that can be mainly explained by the particles and dust attached to the chassis, wheels and fenders of vehicles. The slightly basic pH (7.5) and conductivity (803 μ S/cm) values are within the typical ranges found in common municipal

wastewater. The mean MBAS content (22 mg/L) is nearly the high limit of the concentration interval for typical raw domestic wastewaters (1 to 20 mg/L, APHA 1989). Another important fact shown by the data is the high variability associated with the parameters, specially for O&G, TSS and COD. Without including the pH, which is relatively stable (CV = 8 %), the coefficient of variation (CV%) lays between 18 and 65 % for all the parameters.

For comparison purposes, the mean contaminant levels reported for raw wastewater from a large U.S. commercial truck washing operation (United Tech 2004) were 46 mg/L O&G, 324 mg/L BOD and 8770 mg/L TSS. Except for the O&G concentration, which was lower in the last reported case, the characteristics of the effluents from Full-service wash in Mexico seems similar to the discharges from U.S. commercial truck washing shops. On the other hand, the data provided by Brown (2002b) for U.S. automatic carwash shops (<100 mg/L O&G, 6-117 mg/L TSS and 150-890 mg/L COD) cannot be used for comparison, since they represent the quality of the discharges after certain pretreatment process has taken place (usually by solid and oil traps) in contrast with the present study that deals with raw wastewaters.

The data in Table 4 also show that the effluents from carwash-lubricating facilities require a pretreatment, at least a solid trap and an oil separator (WEF 1995), in order to meet the limits for sewer discharge standards (NOM 02: DOF 1998) regarding the O&G, TSS and BOD contents. Moreover, the free and emulsified oil phases, as well as the solids and soluble organic matter, make a possible direct recycle or reuse quite unfeasible, after the pretreatment of the raw wastewater, due to an inadequate cleaning power (Huang *et al.* 1985). The data provided in Table 4 are also useful for screening the applicable reuse technologies or to develop new ones.

3.4 Evaluation of the performance of the existing oil/water separators

Among all the automotive repair and maintenance sector in Toluca, the Full-service carwash facilities were the ones that more frequently had conventional oil/water separators. However, the oil traps were often too large or conversely had very

small dimensions. Also, even they even had errors in the inlet and outlet location. This may be justified by the lack of specific standards for the design of small gravity separators.

Table 5 presents the results of the evaluation of the existing separators, for a sample of Full-service carwash facilities, regarding the compliance limits of the "NOM 002" standard (DOF 1998) that regulates sewer discharges in Mexico. The data obtained allowed to sort the shops in two groups: one where the oil and grease contents in the pretreated effluents clearly exceeded the Standards (from 142 to 461 mg/L), and another group where the residual oil concentrations remained below or near the limits (<100 mg/L). Five out of the eight separators evaluated fell in the first group. The results of the susceptibility tests (not shown) were consistent with the compliance tendency observed at each shop. Since all the separators selected in this evaluation had a functional design, the degreaser choice may be the most determinant parameter of their oil removal capacity. As reported in Table 5, the whitish aspect of the effluents, a signal of emulsion, was present in all cases where the concentrations were above the limit of the standards, regarding O&G. On the other hand, the data showed that the different types of degreasers used in the sector generate different degrees of emulsion. Based on several field observations, apparently diesel fuel and possibly "Bactium" were the most harmful ones.

In a study done in Switzerland, Paxéus (1996) reported very high values of O&G (10-1750 mg/L) and COD (120 - 4200 mg/L) in the effluent of the separators located in 31 carwash shops and 4 truck washing facilities. The author noticed that most of the separators installed in carwash shops, did not have any efficiency in practice, due to emulsion problems.

Table 5 also shows that the TSS and COD removal in Group 1 was not satisfactory (44 to 596 mg/L TSS and 430 to 3246 mg/L COD). Kim *et al.* (1998) reported the same residual COD problems (100 to 2000 mg/L) in automotive wastewater that was treated by ultrafiltration. The high residual COD, as a potential source of undesirable odor, jeopardizes the direct reuse of the pretreated water (Huang *et al.* 1985).

Table 4. Characteristics of Discharges from Full-service carwash shops

	O&G mg/L	TSS mg/L	VSS % of TSS	TDS mg/L	VDS % of TDS	COD mg/L	pH	Cond μS/cm	MBAS mg/L
Mean	1099	3561	29%	1508	32%	4520	7.5	803	21.8
Minimum	404	728	20%	905	26%	897	7	517	6
Maximum	2876	4887	34%	2442	47%	7814	8.5	1070	35.8
StdD	719	1435	5%	514	8%	2463	0.6	284	12.1
CV(%)	65%	40%	18%	34%	24%	54%	8%	35%	56%
N	10	7	6	6	6	8	8	4	6

O&G: oil and grease, TSS: Total Suspended Solids, VSS: Volatile Suspended Solids, TDS: Total Dissolved Solids, VDS: Volatile Dissolved Solids, Cond: conductivity, MBAS: Methylene Blue Active Substances.
StdD: Standard deviation, CV (%): Coefficient of variation (100 * StdD/Mean), N: Total number of Samples .

Table 5: Performance of Existing Separators in Full-service Carwash Shops

Group of shops #	Shop practices	Statistics	Effluent of the oil/water separators (mg/L)		
			O&G	COD	TSS
Group 1	- Equipped with sufficiently large separators (1.5 to 9 m ² surface with 2 to 5 compartments). - Degreaser brands used: "Bactium", "Galleon" and home-made mix of Roma soap and Diesel fuel - Whitish emulsified effluents	Mean	324	1314	306
		Maximum	461	3246	596
		Minimum	142	430	44
		CV(%)	42%	85%	76%
		N	6	5	5
Group 2	- Equipped with sufficiently large separators (2.1 to 8.7 m ² surface with 2 to 5 compartments). - Degreaser brands used: "FD50 Capitan", "Now Ultra Clean shampoo", "Remobel II", "Limkaw 2" "Deternet Plus shampoo", and detergent "Axion"	Mean	75	355	144
		Maximum	104	675	-
		Minimum	51	143	-
		CV(%)	29%	65%	-
		N	5	4	1
Sewer discharge limits allowed by Mexican Standards ("NOM 002"). *: COD is not regulated.			100	200 (BOD)*	200

CV (%): Coefficient of variation. N : Total number of samples.

Shaded areas indicate the values that overpass the discharge limits. COD is not regulated but it may be inferred that relatively high values of this parameter will probably make the BOD exceeds the limits.

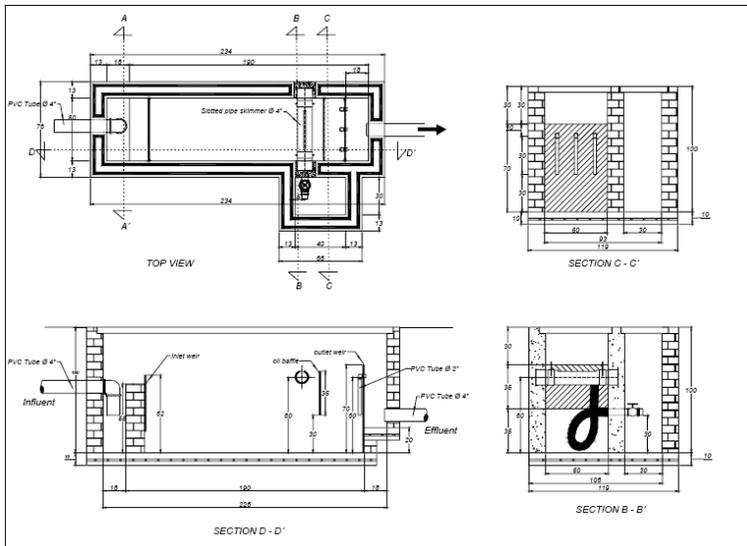


Fig. 1: Design of the prototype separator

Based on the existing experience in carwash shops in the United States, Rosenblum (2001) stated that the rapid generation of odors was a major obstacle for the acceptance of the water reuse concept in this sector. The challenges in developing successful recycling processes are: to appropriately and economically solve the high levels of soluble COD, reduce the potential odors and recover the cleaning power of water without increasing its aggressiveness, that may corrode car bodies when certain disinfection compounds are used. The cost of commercial treatment systems for recycling is between US\$ 30,000 and 60,000 in the U.S. market (Rosenblum 2001), while the average annual income of a carwash shop in Mexico is US\$ 18,000 (estimated from data reported by INEGI in 1999). In this context, providing the carwash-lubricating shops in the country with recycling systems for wastewater

might require the implementation of incentive programs for small carwash shop owners and process designers.

3.5 Performance of the separator prototype installed in one Full-service wash shop

Within the scope of this research, a pilot separator was built and operated in one of the shops. The construction of the prototype was based on a fully supported design criteria (Lopez-Vazquez and Fall 2004), compared to empirically designed tanks found in the carwash sector. The aim of using a pilot plant was to evaluate the limits of this type of technology, in a context that excludes all possible limitations due to bad designs. Details of the construction of the process unit are shown in Figs. 1 and 2. Designed with a nominal flow rate of 38

L/min, a 15 min hydraulic retention time and 2.5 m/h superficial loading rate, the prototype (Fig. 1) was 0.6 m deep, 0.5 m wide and 1.8 m long (between the weirs). To facilitate the maintenance and handling of oil residues, the installation was provided with a slotted-pipe skimmer system (API 1990) connected to an oil deposit.



Fig. 2: Photograph that shows the details of the skimmer, oil baffle and outlet weir of the Prototype separator

Three hours after the shop started its regular daily activities, on the evaluation day, 4 hourly grab samples were taken at the inflow and outflow. Fig. 3 shows the results obtained (influent vs effluent). In addition, Table 6 shows the statistics regarding the effluent quality and removal efficiencies (separator and susceptibility test).

As perceived in Fig. 3 and latter confirmed by computing the coefficient of variation (CV% = 22 to 49%, Table 6), the influent characteristics were quite variable, but consistent with the general average and variability trends previously observed for discharges in the sector (Table 4). The O&G, COD and TSS variability at the influent was expected because of the different phases of the car-washing process. However, the variability was also present at the outflow of the separator (CV% = 8 to 50%, Table 6), even if the scale of Fig. 3 does not make it evident. There was a relatively important reduction of TDS in the separator (40% on average, Fig. 3d), which could be explained, partially, by the absorption of

dissolved organic compounds on the suspended solids and their simultaneous separation by sedimentation. This phenomenon, related to surfactants, has been reported by APHA (1989) as a possible source of interference in the MBAS analysis method. The hypothesis presented was in accordance with the observed reduction of the volatile fractions in the dissolved solids, from 34 %, in the influent, to 30 %, in the effluent (Table 6, VSD column).

The mean removal efficiencies for the different parameters (O&G, COD and TSS) were as high as 80, 74 and 88 % respectively, but not enough to comply with the requirements for discharge in the sewage system or to reach a quality level, which would make its reuse feasible. The average concentration of O&G that was obtained in the susceptibility tests (185 mg/L) showed that the difficulty to reach concentrations below 100 mg/L is not a limitation of the separator design, as it was also established with the existing separators. In addition, the high levels of residual solids may not be attributed to the design of the separator. In the site where the prototype was installed, the wastewater flows along an open channel (more than 12 m long, sufficiently wide and deep) where solids that may be separated by gravity should settle. Additionally, some solids might be removed in the solid trap of the separator. Thus, it seems that simple sedimentation is not sufficient to treat this type of wastewater. The wastewater characteristics are far beyond the applicability field of the conventional oil/water separation processes.

Based on the results of this study, the efforts to improve the performance of oil gravity separator to treat wash waters must be directed: first, to make an adequate selection of the degreaser, and mainly, to prohibit the use of diesel as degreasing agent; and second, to implement an additional coagulation-based process to break the emulsions; this also may lead to an improvement of the solids removal. Undoubtedly, these measures would contribute to the compliance with the discharge limits regarding O&G and TSS.

Table 6. Statistics from the evaluation of the prototype (based on 4 hourly samples).

	O&G mg/L	COD mg/L	TSS mg/L	VSS % of TSS	TDS mg/L	VDS % of TDS	MBAS mg/L
Influent							
Mean	953	5149	3844	28%	1313	34%	-
CV(%)	49%	39%	22%	22%	23%	27%	
Effluent							
Mean	143 (185)*	1071	421	35%	757	30%	(28.4)
CV(%)	36% (14%)	9%	50%	40%	8%	12%	(29%)
Efficiency							
** Mean	80% (71%)	74%	88%	87%	40%	46%	-
CV(%)	21% (26%)	23%	8%	7%	27%	29%	

* : (...) = measured values from the susceptibility test effluents.

** : mean of the individual removal efficiencies from each sample (calculated based on the concentrations expressed in mg/L).

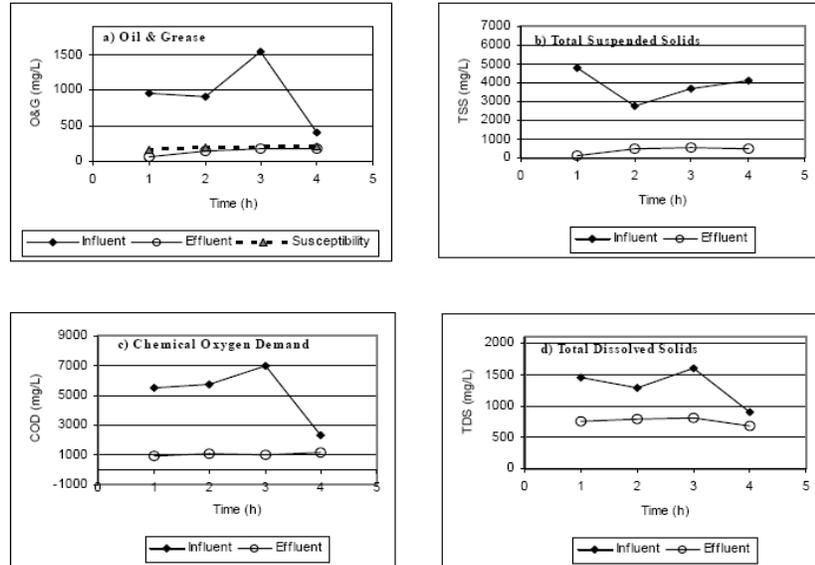


Fig. 3: Performance of the prototype separator

If in a certain case, the economical conditions allow the replacement of the traditional gravity oil separators and this is combined with an interest in water reuse, then several alternative technologies in the literature claim to be able to reach the required quality: polyelectrolyte coagulants, coalescers, adsorbents, ultrafiltration, reverse osmosis, sand and mechanical filtration, ozonation and biological process, among others (Kim et al. 2002; Brown 1999 and Kim et al. 1998).

Conclusions

This study was carried out in a limited number of sites in Toluca, thus the results are not universal, but highlight and depict the environmental problematic and technological needs, as well as provide some pertinent data for pollution control in the Mexican automotive maintenance sector.

Regarding carwash facilities, the average water use and service time for Exterior-only wash were estimated around 50 L and 20 minutes per vehicle for compact and subcompact cars and, approximately, at 170 L and 30 minutes for light trucks and vans. In Full-service car washing (body, motor and chassis), the average volumes needed were 190 L of water per vehicle for small cars (and the service lasted slightly longer than an hour), and 300 L (in 88 minutes) for light trucks. For a 10-ton truck, more than 600 L were used in a period of one hour and a half, meanwhile, 1100 L of water and three and a half hours of work were required for a heavy truck.

Wastewaters from carwash-lubricating facilities are characterized by high loads of oils and greases (404 - 2876 mg/L), COD (897 - 7814 mg/L)

and TSS (728 - 4887 mg/L). Suspended solids mostly comprised inorganic matter (20 - 34 % VSS). In addition, wastewaters usually present emulsions due to the use of degreasers and detergents (28.4 mg/L MBAS on average).

Based on the performance of the gravity oil/water separators evaluated in the Full-service carwash sector (prototype and existing processes), it can be concluded that this technology, by itself, does not allow producing an effluent that complies with the discharge limits established for the sewage system and does not satisfy the quality required to make the reuse feasible. The ranges of residual concentrations in the treated water were 51 - 461 mg/L of O&G, 430 - 3246 mg/L of COD and 44 - 596 mg/L of TSS. The results from this study demonstrate that the limits of the technology, regarding oils and greases, COD and TSS removals (even though efficiencies as high as 80 % were observed) are not deficiencies that can be attributed to the separator design by itself, but mainly to the wastewater characteristics which go beyond the field of its applicability.

To be able to meet the sewer discharge standards, the use of a conventional oil/water separator type would require to make an adequate selection of degreasers and implement an additional process to break the emulsions and enhance solid settling.

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